CAL Document Change Notification

DCN No. 7650-DCN-0080-01

CHANGE TITLE: CAL Assembly And Test Plan, Update To Flight Flow

☒ **Internal** ☐ **External**

ORIGINATOR: J. Eric Grove **DATE:** 30-Aug-04 **NEXT ASSY:**

DOC or DWG NUMBER	TITLE	AFFECTED REV.	NEW REV.
LAT-SS-00262	CAL Assembly And Test Plan	02	03

CHANGE DESCRIPTION:

1. Modifed assembly and test flow to reflect plan for Flight units. Modest clarifications and minor changes throughout.
2. Modified document number from "SS" to "MD" category.

REASON FOR CHANGE:

These changes were made to reflect lessons learned from EM assembly and test.

DISPOSITION OF HARDWARE:

☐ **No hardware affected**

☒ **Serial numbers affected:** All CAL Modules **Effective date:** 30-Aug-04

	Use as is	Retest	Rework	Scrap	Other/Comment
Raw material	☐	☐	☐	☐	
Parts in process	☐	☐	☐	☐	
Assemblies	☒	☐	☐	☐	

APPROVALS		DATE	OTHER APPROVALS (specify):	DATE
ORIGINATOR:	*J. Eric Grove*	30-Aug-04	**SYSTEMS ENGINEER:** *Paul V. Dizon*	30-Aug-04
SUBSYSTEM MANAGER:	*W. Neil Johnson*	30-Aug-04	:	
PROJECT MANAGER:	*William C. Raynor*	30-Aug-04	:	
QUAL ASSUR. MANAGER:	*Nick Virmani*	30-Aug-04	:	
CONFIGURED AND RELEASED:	*P. Sandora*	30-Aug-04		

	Document #	Date Effective
GLAST LAT MANAGEMENT DOCUMENT	**LAT-MD-00262-03**	20 August 2004
	Prepared by(s) J. Eric Grove	Supersedes None
	Subsystem/Office Calorimeter Subsystem	
Document Title **Calorimeter Module Assembly & Test Plan**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter Module Assembly & Test Plan

DOCUMENT APPROVAL

Prepared by:

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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
01	13 July 2001	Initial Release
02	17 January 2003	Reorganization
03	20 August 2004	Modified to reflect flight flow

Table of Contents

1 INTRODUCTION

1.1 PURPOSE

This document specifies the plan for assembly and test of Calorimeter Modules.

1.2 SCOPE

The assembly and test sequence specified in this document applies to all Flight Calorimeter Modules.

1.3 APPLICABLE DOCUMENTS

Documents and drawings that are applicable to this procedure are listed below.

1.3.1 Documents

GSFC-433-MAR-0004	GLAST Mission Assurance Requirements for the Large Area Telescope Phase C/D/E
NASA-STD-8739.7	Electrostatic Discharge Control
LAT-SS-00115	LAT Mechanical Systems – Level III Specification
LAT-MD-00408	LAT Program Instrument Performance Verification Plan
LAT-SS-00210	LAT-CAL Subsystem Level IV Specification
LAT-SS-00222	Calorimeter Module Assembly, Test, and Calibration Requirements
LAT-PS-04454	CAL Flight Module Vibration Test Procedure
LAT-PS-04455	CAL Flight Module Thermal Vacuum Test Procedure
LAT-PS-03989	CAL Subsystem Electromagnetic Interference Test Procedure
LAT-PS-01370	Comprehensive and Limited Performance Test Definition
LAT-PS-04187	Calorimeter Muon Telescope Requirements Specification
LAT-PS-03547	CAL Procedure for Cleaning of Polymer Parts
LAT-PS-03548	CAL Procedure for Preparation of Composite Structure
LAT-PS-03363	CAL Base Plate Assembly Procedure
LAT-PS-01231	CAL Pre-Electronics Module Mechanical Structure Assembly Procedure
LAT-PS-01225	CAL Pre-Electronics Module (PEM) Assembly Procedure
LAT-PS-03677	Flight PEM Checkout: Muon Optical Test Procedure
LAT-SS-03781	Calorimeter Flight Model Pre-Electronics Module Acceptance Requirements
LAT-PS-03683	Calorimeter PEM to Tower Module Assembly Procedure
LAT-PS-03933	LAT Calorimeter TEM Mating and Verification Procedure
LAT-MD-01370	Comprehensive and Limited Performance Test Definition
LAT-DS-03395	Shipping Container, GLAST Calorimeter
LAT-PS-03929	CAL EMC/EMI Test Procedure
LAT-DS-03323	EMC/EMI Test Bed
LAT-SS-00231	Calorimeter Performance Acceptance Standards and Tests
LAT-SS-1498	AFEE Board Verification Plan
LAT-SS-1335	AFEE Board Test Procedure

1.4 ACRONYMS

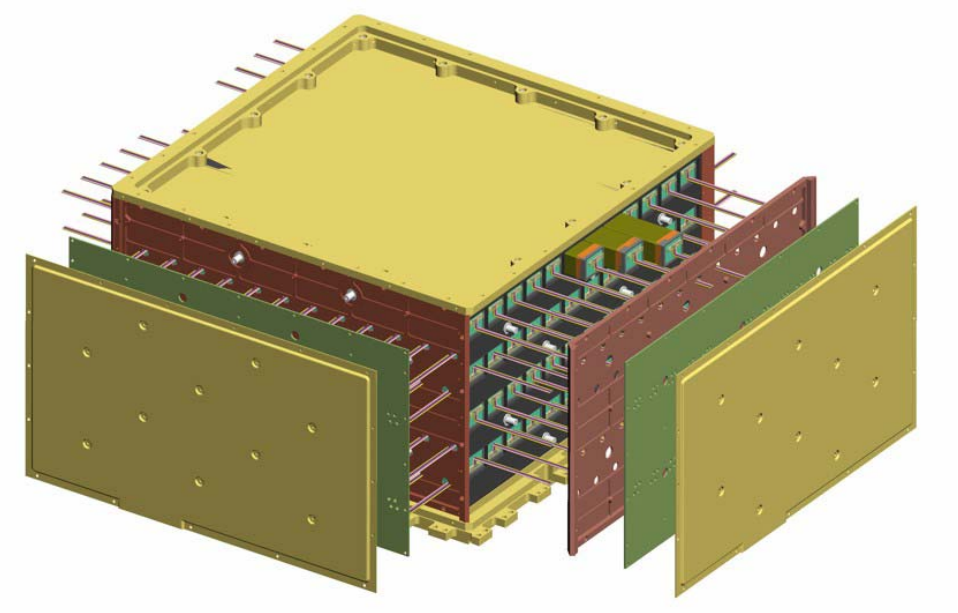
1.4.1 Acronyms

AFEE	Analog Front End Electronics of the Calorimeter
CAL	Calorimeter Subsystem of the LAT
CDE	Crystal Detector Element of the PEM
CES	PEM Checkout Electronics System
CMM	Coordinate Measuring Machine
CPT	Comprehensive Performance Test
CsI	Cesium Iodide
CTS	Calorimeter Test Stand
DAS	Data Acquisition System
EC	Electronic Calibration
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FHE	Fast High Energy
FLE	Fast Low Energy
FM	Flight Module
GLAST	Gamma-Ray Large Area Space Telescope
GSE	Ground Support Equipment
LAT	Large Area Telescope
LPT	Limited Performance Test
MGSE	Mechanical Ground Support Equipment
MuC	Muon Calibration
NRL	Naval Research Laboratory
PDA	Photo-Diode Assembly
PEM	Pre Electronic Module of the CAL
QE	Quality Engineer
QM	Qualification Module
RFI	Ready For Integration
SAS	Science Analysis Software
SLAC	Stanford Linear Accelerator Center
TEM	Tower Electronics Module
TPS	TEM Power Supply
WOA	Work Order Authorization

2 ASSEMBLY & TEST PROCESS

2.1 Overview

Error! Reference source not found. shows the Calorimeter Module in an exploded view. The Module consists of the core Composite Structure, CDEs, Closeout Plates, AFEE boards and Side Panels. The Pre-Electronics Module (PEM) consists of the Composite Structure, CDEs, and Closeout Plates, i.e. it is the Module prior to attachment of AFEE boards and Side Panels. The articles of test within this document are the assembled PEM and assembled CAL Module. A total of 18 Flight CAL Modules shall be constructed.



2.2 Assumptions

This document was developed under the following assumptions:

Figure 1: Exploded view of Calorimeter Module

1. Composite Structures and Side Panels are built by IN2P3 and delivered to NRL.
2. Top Frames, Base Plates, and Closeout Panels are built by NRL.
3. TEM Standoffs are built by SLAC and delivered to NRL. Until SLAC completes the manufacture of flight TEM standoffs, NRL will build and install standoffs to take their place during A&T processing at NRL.
4. Crystal Detector Elements (CDE) are assembled by Swales Aerospace and delivered to NRL.
5. Pre-Electronics Modules (PEM) are assembled at NRL.
6. Analog Front End Electronics (AFEE) boards are built by NRL.
7. AFEE boards are tested and validated prior to integration with the PEM.
8. This sequence includes acceptance tests for the PEMs, but it assumes that elements to be integrated with the PEMs – the AFEE boards, Calorimeter Tower Electronics Modules (TEMs), and Tower Power Supplies – are accepted and verified separately, prior to entry into this sequence.

2.3 Module-Level Performance Tests

Functional and performance tests of at least three types are performed on the completed CAL Tower Module as part of the Assembly and Test sequence. A brief description of these tests is given here. Details of these tests are given in the relevant documents specified below.

2.3.1 Comprehensive Performance Test (CPT)

The Comprehensive Performance Test, defined in LAT-PS-01370, is comprised of a suite of tests intended to measure the performance and test the functionality of all operating modes and conditions of the CAL Tower Module, and to confirm compliance with operating and performance requirements as an integrated whole. Data from the CPT are analyzed by the on-line EGSE software, compliance is tested, and reports are generated.

2.3.2 Limited Performance Test (LPT)

The Limited Performance Test, defined in LAT-PS-01370, is a subset of the CPT. It tests communication between the TEM and CAL Module and a modest number of basic CAL functions. Data from the LPT are analyzed by the on-line EGSE software, compliance with requirements is tested, and reports are generated.

2.3.3 Muon Calibration (MuC)

The Muon Calibration, defined in LAT-PS-04187, is designed to test the end-to-end performance of the CAL Tower Module. The Module is configured to trigger on sea-level cosmic ray muons. Data accumulations of at least 8 hours are required to generate statistically significant performance calibrations. Note that the CPT includes muon data accumulations of ~10 minutes, which are adequate to verify that scintillation signals are read out and digitzed and that no dramatic changes (i.e. changes greater than roughly 30%) have occurred in the optical bonds of each CDE within the Module.

There are two forms of MuC, the first with CAL internally triggering ("self-triggering") on muons, and the second with an ancillary detector generating external triggers for the CAL Tower Module. The self-triggered MuC is simpler and requires no additional hardware, but it results in a modestly biased energy calibration. The externally triggered MuC does not create a biased calibration, and therefore is used to generate the final energy calibration of each channel.

2.3.4 Electronic Calibration (EC)

The Electronic Calibration, defined in LAT-PS-04187, is comprised of a suite of tests intended to provide detailed calibrations of the electronic gain of the spectroscopy channels, trigger threshold settings, and zero-suppression settings. Data from the EC are analyzed by the on-line EGSE software and calibration tables are generated. More detailed analysis intended to provide more detailed calibration tables may be performed at a later date.

3 ASSEMBLY AND TEST SEQUENCE

The following assembly and test sequence applies to each of the Calorimeter Modules. A flow chart of this sequence is shown in Figure 2 and Figure 3, where it is divided into seven general themes:

1) PEM assembly
2) Electronics integration
3) Calibration and characterization
4) Environmental testing
5) Pre-ship verification
6) Shipment and sign-off

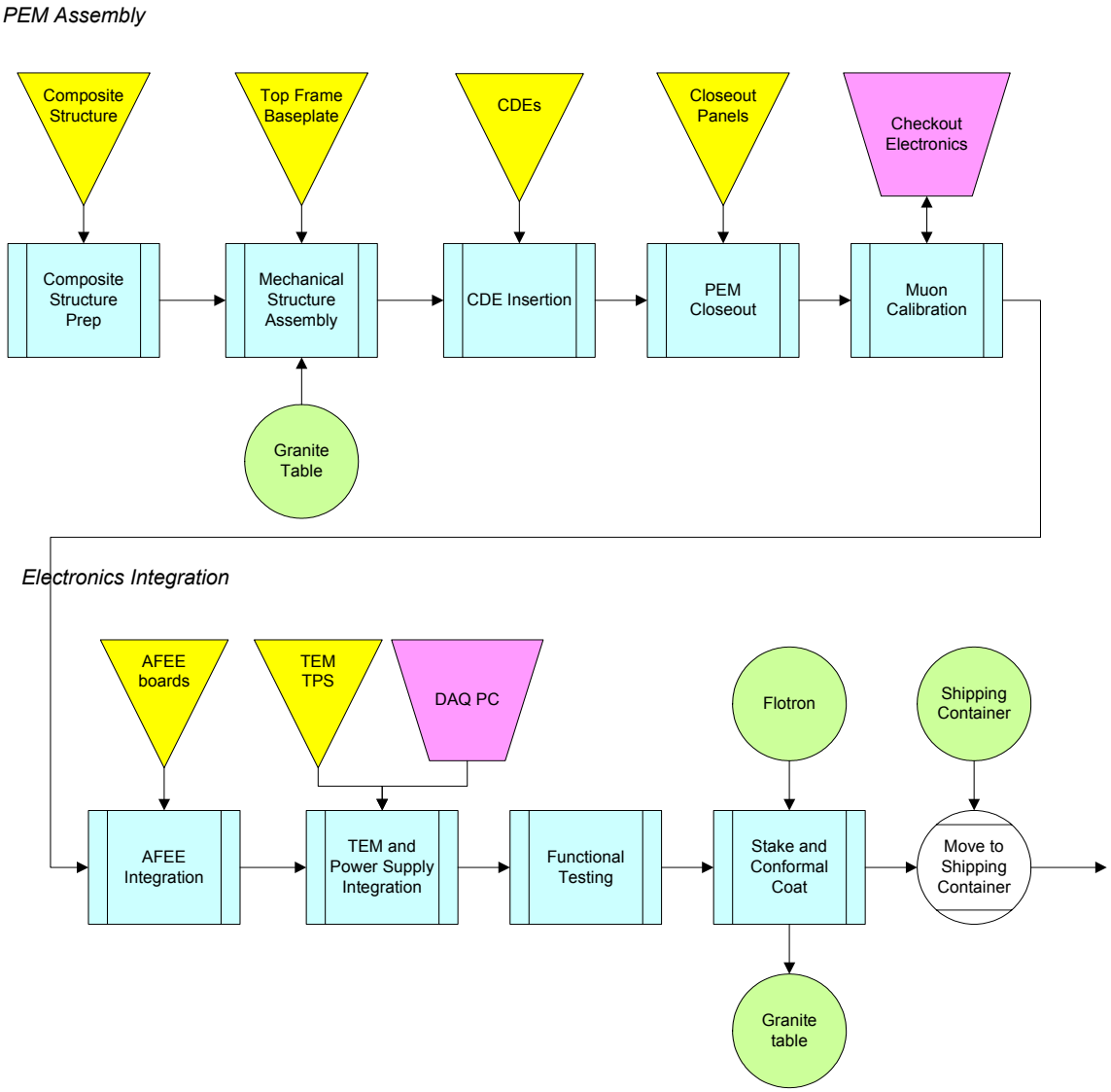


Figure 2: Initial steps of assembly and test flow

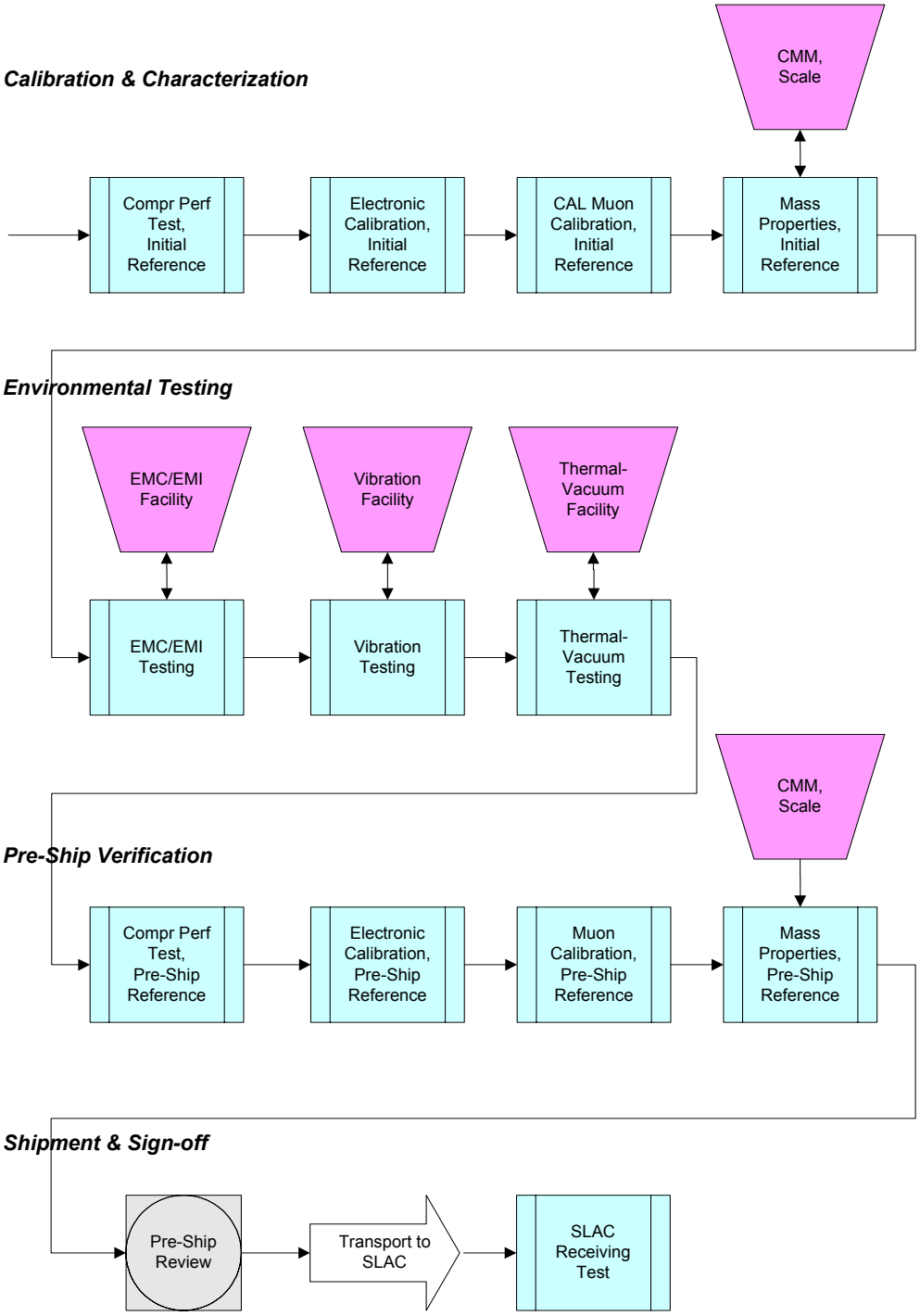


Figure 3: Remainder of assembly and test flow

Each step in the assembly and test sequence is outlined below. A more complete description of each step is given in Section 3.

1. Receive Composite Structure, mechanical parts, and CDEs at NRL – Comparison with shipping logs to confirm identity of items shipped. Visual inspection for shipping damage.

2. Composite Structure Preparation – Inspect and clean up cells of Composite Structure.
3. Mechanical Structure Assembly – Attach metal parts to Composite Structure. Inspect.
4. Crystal Detector Element Integration – Install CDEs in PEM Mechanical Structure. Inspect.
5. PEM Closeout – Integrate Closeout Plates. Inspect.
6. PEM Muon Optical Calibration – Install PEM Checkout Electronics onto PEM. Collect cosmic muons. Verify quality of PDA optical bonds. Remove Checkout Electronics. Document results. .
7. AFEE Integration – Integrate AFEE boards and solder CDE wires. Inspect.
8. TEM and Power Supply Integration – Integrate TEM and TPS. Test. Inspect.
9. PDA Wire Staking and Coating – Stake PDA wires near solder joint on AFEE board. Conformal-coat PDA solder joints. Test. Inspect.
10. Comprehensive Performance Test, Initial Reference – Establish full functionality of integrated CAL Module. Analyze and document results.
11. Electronic Calibration, Initial Reference – Charge injection calibration. Analyze and document results.
12. CAL Muon Optical Calibration, Initial Reference – Establish baseline gain of integrated system. Analyze data. Compare with PEM-CES response and known gain of AFEE. Document results.
13. Mass Properties Measurement, Initial Reference – Establish weight and physical dimensions of CAL Tower Module.
14. EMC/EMI Testing – Establish electromagnetic noise production and susceptibility. Document results.
15. Vibration Testing – Establish robustness against transportation and launch environment. Functional Test. Document results.
16. Thermal-Vacuum Testing – Establish performance of CAL Tower Module over qualification or acceptance temperature range. Perform thermal balance test. Functional Test. Document results.
17. Comprehensive Performance Test, Pre-Ship Reference – Establish no degradation in operation during Environmental testing and handling. Establish reference performance prior to shipment to SLAC.
18. Electronic Calibration, Pre-Ship Reference – Establish no degradation in operation during Environmental testing and handling. Establish reference calibration prior to shipment to SLAC.
19. Muon Calibration, Pre-Ship Reference – Establish no degradation in performance during Environmental testing and handling. Establish reference optical performance and calibration prior to shipment to SLAC.
20. Mass Properties Measurement, Pre-Ship Reference – Establish no change in weight or physical dimensions of assembled CAL Tower Module during Environmental testing.
21. Pre-ship Review – Establish readiness for delivery.
22. Transport to SLAC.
23. SLAC Receiving Test – Formal Acceptance Test for delivery CAL Tower Module.

Details of each activity are given in the following subsections. The durations of the activities are listed for the individual PEMs or Modules. Generally, we have allowed more time for each activity for the earlier PEMs, under the assumption that with practice the procedures will move more quickly and efficiently.

3.1 Receipt Inspection

The Composite Structure, Top Frame, Base Plate, Shear Pins, Closeout Panels, Elastic Cords, Bumper Frames, and Crystal Detector Elements will be received at NRL's A&T Cleanroom. The components will be removed from their shipping containers and inspected by NRL Quality Assurance personnel for item identification against the shipping papers. A visual inspection will be made to ascertain the condition of the hardware and to note any visual abnormalities. Elastomeric parts will be cleaned in accordance with LAT-PS-03547, CAL Procedure for Cleaning of Polymer Parts. Receipt status and comments will be entered into the CDE Inventory Spreadsheet and CAL Assembly Database.

3.1.1 Facilities and GSE

Receiving inspections take place in the Inspection Area and the A&T Cleanroom of Building A59 at NRL.

3.1.2 Reporting

Receipt status and comments will be entered into the parts inventory, the CDE Inventory Spreadsheet, and CAL Assembly Database.

3.1.3 Personnel

The duration and personnel required for this task are listed below.

Module	Duration (days)	Personnel
A – B	3	1 Scientist, 2 Technicians, 1 QE
1 – 16	2	1 Technician, 1 QE

3.2 Composite Structure Preparation

In accordance with LAT-PS-03548, the Composite Structure will be prepared for assembly and CDE insertion. The opening of each cell of the Composite Structure will be inspected for resin flash from the structure manufacturing process. Any flash will be removed. To ease the CDE insertion and reduce the rate of breakage of elastic cords, the four corners of the opening of each cell will be radiused. After these operations, the Composite Structure will be cleaned.

3.2.1 Facilities and GSE

Inspection and rework will take place in the Inspection Area of Building A59 at NRL.

3.2.2 Reporting

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.2.3 Personnel

The duration and personnel required for this task are listed below for each Composite Structure.

Structure	Duration (days)	Personnel
A, B	2	1 Engineer, 2 Technicians, 1 QE
1 – 16	1	1 Technician, 1 QE

3.3 Mechanical Structure Assembly

Shear pins will be installed into the Base Plate in accordance with LAT-PS-03363, CAL Base Plate Assembly Procedure. If they are available, TEM Standoffs will be installed into the Base Plate in accordance with LAT-PS-03363. (The design and machining of TEM Standoffs was not completed by SLAC before we began the assembly of the first Modules; for those Modules, the Standoffs will be installed as part of the TEM attachment procedure.)

The PEM Mechanical Structure will then be assembled from the Composite Structure, Top Frame, and Base Plate assembly in accordance with LAT-PS-01231, CAL PEM Mechanical Structure Assembly Procedure. The attached Top Frame and Base Plate will be inspected for planarity and alignment. The serial numbers of the component parts of each PEM will be entered into the CAL Assembly Database.

3.3.1 Facilities and GSE

Insertion of shear pins takes place in the Inspection Area of Building A59 at NRL. Assembly of the PEM Mechanical Structure takes place in the A&T Cleanroom. Inspection of the assembled Mechanical Structure uses a Coordinate Measuring Machine.

3.3.2 Reporting

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.3.3 Personnel

The duration and personnel required for this task are listed below for each Mechanical Structure.

Structure	Duration (days)	Personnel
A, B	3	1 Engineer, 2 Technicians, 1 QE
1 – 16	2	2 Technicians, 1 QE

3.4 CDE Integration

The Mechanical Structure will be mounted on the Assembly Platform, and the CDE Insertion Tooling will be attached. CDEs will be inserted into the Mechanical Structure in accordance with LAT-PS-01225, CAL Pre-Electronics Module Assembly Procedure. CDEs may be selected for a particular Structure or Structure face according to their optical performance or mechanical properties. The location of each CDE will be entered into the CAL Assembly Database. The elastic cords and Bumper Frames will be tracked by lot number in the Work Order Database.

When insertion is completed, the CDE Insertion Tooling will be removed, and the PEM will remain on its Assembly Platform.

3.4.1 Facilities and GSE

CDE insertion takes place in the A&T Cleanroom. The Mechanical Structure and CDE Insertion Tooling are mounted on the PEM Assembly Platform on a granite table.

3.4.2 Reporting

The location of each CDE within the PEM shall be documented in a CDE Insertion Map spreadsheet as part of the insertion procedure, as instructed in LAT-PS-01225, and the corresponding WOA. This spreadsheet is then imported into the CAL Assembly Database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.4.3 Personnel

The duration and personnel required for this task are listed below for each PEM. The QE is responsible to verify CDE serial numbers and document their locations in the WOA.

PEM	Duration (days)	Personnel
A, B	10	1 Scientist, 1 Engineer, 2 Technicians, 1 QE
1 – 3	3	2 Technicians, 1 QE
4 – 16	2	2 Technicians, 1 QE

3.5 PEM Closeout

Closeout plates, EMI gaskets, and Corner Closeouts will be installed onto the Mechanical Structure in accordance with LAT-PS-01225, CAL Pre-Electronics Module Assembly Procedure. At this point, mechanical assembly of the PEM is completed.

3.5.1 Facilities and GSE

Closeout Plate integration takes place in the A&T Cleanroom. The Mechanical Structure is mounted on the PEM Assembly Platform on a granite table.

3.5.2 Reporting

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.5.3 Personnel

The duration and personnel required for this task are listed below for each PEM. The QE is responsible to verify completion of this task.

PEM	Duration (days)	Personnel
A, B	3	1 Engineer, 2 Technicians, 1 QE
1– 16	1	2 Technicians, 1 QE

3.6 PEM Muon Optical Calibration

The PEM will be integrated with the PEM Checkout Electronics System (PEM-CES) in accordance with LAT-PS-03677. The PEM-CES provides simultaneous, 384-channel readout of all PIN photodiodes. After integration, the technicians will perform functional tests to establish that all channels are alive, being properly digitized, and logged to disk.

Data from cosmic muons will then be accumulated for at least 24 hours according to the procedure in LAT-PS-03677.

Following the run, the data will be analyzed by PEM EGSE software to derive scintillation light yields and light tapering response maps. The relative light yields and light-tapering functions from the muon calibration will be compared to the calibration performed on the CDEs as they were assembled at Swales Aerospace. Analysis results and raw calibration data will be archived to a long-term storage medium.

Following a successful calibration, the PEM-CES will be disintegrated from the PEM and PEM Assembly Platform. The PEM will remain on the Assembly Platform.

3.6.1 Facilities and GSE

PEM muon calibration takes place in the A&T Cleanroom. The PEM and PEM-CES are mounted on the PEM Assembly Platform on a granite table. Data acquisition is performed by the CES PC.

3.6.2 Reporting

The muon calibration software generates a test report that summarizes compliance with CDE optical specs and similarity with the performance established for each CDE during its assembly at Swales. The test report shall be referenced in the CAL Module deliverable data package.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

At the conclusion of the PEM muon calibration, an acceptance review of all PEM assembly and test data shall be conducted to verify that the PEM meets the requirements specified in LAT-PS-03781 (Flight PEM Acceptance Requirements).

3.6.3 Personnel

The duration and personnel required for this task are listed below for each PEM. The scientist is responsible to verify the data analysis. The QE is responsible to verify completion of the test and log data into the Assembly Database. The QE shall also direct the PEM acceptance review.

PEM	Duration (days)	Personnel

A	10	1 Scientist, 2 Technicians, 1 QE
B	7	1 Scientist, 2 Technicians, 1 QE
1 – 16	5	1 Scientist, 1 Technician, 1 QE

3.7 AFEE Integration

The four Analog Front End Electronics boards will be mechanically attached, and the 384 PDA wire pairs soldered to the Front End boards, in accordance with LAT-PS-03683 (PEM to Tower Module Assembly Procedure). Prior to attachment, the QE will verify that each AFEE board has successfully passed its acceptance test program (LAT-SS-1498), and that the PEM has satisfied its acceptance requirements (LAT-SS-03781). As each board is integrated, solder joints will be inspected by the QE.

The integrated PEM and AFEE form a completed CAL Module.

3.7.1 Facilities and GSE

The AFEE board integration is performed on the granite table, with the PEM mounted on the Assembly Platform.

3.7.2 Reporting

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.7.3 Personnel

The duration and personnel required for this task are listed below for each PEM. The QE will be responsible to inspect the solder work in progress and at completion.

PEM	**Duration (days)**	**Personnel**
A, B	3	1 Scientist, 1 Engineer, 2 Technicians, 1 QE
1 – 16	3	2 Technicians, 1 QE

3.8 Tower Electronics Module and Power Supply Integration

The CAL Module will be lifted from the Assembly Platform and granite table, the four CAL legs will be mounted to the Base Plate, and the Module will be mounted in the CAL Turnover Fixture. An EM2 Tower Electronics Module (TEM) and EM2 power supply (TPS) will then be integrated with the CAL Module in accordance with LAT-PS-03683 (PEM to Tower Module Assembly Procedure). The CAL Side Panels will then be temporarily tacked in place to provide EMI shielding and optical closeout.

Prior to their attachment to the CAL, the QE shall verify that the TEM and TPS have successfully completed the acceptance test given in LAT-PS-03933 (TEM Mating and Verification Procedure).

Following LAT-MD-01370, Comprehensive and Limited Performance Test Definition, a power-up and Comprehensive Performance Test will be performed on the integrated Module and TEM/TPS. This CPT shall include a muon data collection of at least 4 hours. The CPT provides confirmation that all electrical contacts are made, that all electrical channels are performing with acceptable standards, and that the optical performance of each CDE is acceptable.

Any required rework or repair of PDA solder joints or AFEE board components will be performed on the CAL Turnover Fixture. If any rework or repair occurs, the complete LPT shall be performed again.

The integrated CAL Module, TEM, and TPS form a completed CAL Tower Module.

3.8.1 Facilities and GSE

Integration of EM2 TEM and TPS will occur with the CAL Module mounted in the Turnover Fixture (LAT-DS-###).

The TEM and TPS are EGSE items. Flight model TEM and TPS will be integrated at SLAC.

The Calorimeter Test Stand (CTS) command and data acquisition system is required to operate the CAL Tower Module.

3.8.2 Reporting

The CPT performed after TEM and TPS integration generates a standard test report. Performance and health/safety data from this CPT are used to start the trending database for each CAL Tower Module.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.8.3 Personnel

The duration and personnel required for this task are listed below for each Module. The QE is responsible for in-process inspection of cabling and any rework.

Module	Duration (days)	Personnel
A, B	2	1 Engineer, 2 Technicians, 1 QE
1 – 16	2	2 Technicians, 1 QE

3.9 PDA Wire Staking and Coating

Following successful completion of the CPT, the Side Panels will be removed, and all PDA solder joints with the AFEE boards will be staked and conformal-coated in accordance with LAT-PS-03683 (PEM to Tower Module Assembly Procedure), with the CAL Module mounted horizontally on the CAL Turnover Fixture. After the staking and coating is completed, the Side Panels will be tacked back into place, and the LPT will be executed and compared to the pre-staking CPT.

The staking material and the conformal coating material must be allowed sufficient time to cure before the CAL is rotated from horizontal with a particular face upward. LPTs may be performed during the curing times. In addition, at the discretion of the A&T Manager, absolute calibration of the electronic gain of the AFEE may be performed with a ^{57}Co sheet source in accordance with LAT-PS-04626.

The QE shall inspect the staking and coating after curing. The test technician shall verify successful completion of the LPTs.

3.9.1 Facilities and GSE

Staking and conformal-coating operations will occur with the CAL Tower Module mounted in the Turnover Fixture (LAT-DS-###).

The CTS system is required to operate the CAL Tower Module.

3.9.2 Reporting

The LPT generates a standard test report.

A subset of the calibration constants and housekeeping data from the LPT will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.9.3 Personnel

The duration and personnel required for this task are listed below for each Module. The QE is responsible for final inspection of staking and coating.

Module	Duration (days)	Personnel
A, B	4	1 Engineer, 2 Technicians, 1 QE

1 – 16	4	1 Technician, 1 QE

3.10 Comprehensive Functional Test, Initial Reference

The integrated CAL Tower Module will be removed from the Turnover Fixture and mounted in its Shipping Container (LAT-DS-03395). The base of the Shipping Container has been designed to hold the CAL Tower Module and allow it to operate during testing, calibration, and transportation between the environmental test sites in Building A59 at NRL.

The CAL Module and TEM will be subjected to comprehensive performance and functional testing to confirm compliance with operating and performance requirements as an integrated whole. The contents of the Comprehensive Performance Tests (CPT) are specified in LAT-MD-01370. Portions of the CPT repeat elements of the AFEE checkout tests. Functionality will be compared with AFEE checkout to confirm no loss of performance. Test results and performance summary will be logged to the CAL Assembly Database.

This CPT will serve as a reference for further, repeated CPTs during subsequent assembly and test processes.

3.10.1 Facilities and GSE

The CAL Tower Module will be mounted in the base of its Shipping Container (LAT-DS-03395).

The CTS system is required to operate the CAL Tower Module.

3.10.2 Reporting

The CPT generates a standard test report that summarizes compliance with CAL performance specifications. This test report will be used as a reference against which subsequent functional tests may be compared.

A subset of the calibration constants and housekeeping data from CPT will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.10.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	**Duration (days)**	**Personnel**
A, B	2	2 Scientist, 2 Engineers, 2 Technicians, 1 QE
1 – 2	1	1 Scientist, 2 Engineers, 1 Technician, 1 QE
3 – 16	1	1 Scientist, 1 Engineer, 1 Technician, 1 QE

3.11 Electronic Calibration, Initial Reference

The CAL Module will be calibrated following the Electronic Calibration procedure (LAT-MD-04187). This calibration includes a charge-injection calibration of each of the 768 analog and digital electronics channels, a calibration of all 192 FLE and 192 FHE discriminators, a calibration of all 192 log-accept thresholds, and a calibration of the range upper-level discriminators. Charge is injected into each analog front end at a high repetition rate covering the full dynamic range of the electronics. Data will be logged to the CTS and analyzed with EGSE software. Test results and calibration data will be archived to a long-term storage medium. .

3.11.1 Facilities and GSE

The CAL Tower Module will be mounted in the base of its Shipping Container (LAT-DS-03395).

The CTS system is required to operate the CAL Tower Module.

3.11.2 Reporting

The electronic calibration software generates a test report that summarizes compliance with CAL performance specifications. This test report will be used as a reference against which subsequent electronic calibrations may be compared. In addition, off-line analysis of the calibration data generates a table of calibration constants that are used in the SAS environment.

A subset of the calibration constants and housekeeping data from the electronic calibration will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.11.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A, B	2	1 Scientist, 2 Engineers, 2 Technicians, 1 QE
1 – 16	1	1 Scientist or Engineer, 1 Technician, 1 QE

3.12 CAL Muon Optical Calibration, Initial Reference

The CAL Module will be calibrated with cosmic muons in accordance with LAT-MD-04187. This calibration will be performed with the CAL self-triggering.

Muons will be accumulated for not less than 40 hours, with triggers generated internally by the CAL Module. Following the run, the data will be analyzed by EGSE software to derive scintillation light yields and light tapering response maps for the individual CDEs. The results of this run will be logged in the CAL Assembly Database. The relative light yields and light-tapering functions from the muon calibration will be compared to the pre-environmental-test response to confirm no change in instrument performance.

Test results and raw calibration data will be archived to a long-term storage medium.

Following the successful completion of the Muon Optical Calibration, the CAL Side Panels shall be torqued and staked in place, in accordance with LAT-PS-03683 (PEM to Tower Module Assembly Procedure).

3.12.1 Facilities and GSE

The CAL Tower Module will be mounted in the base of its Shipping Container (LAT-DS-03395).

The CTS system is required to operate the CAL Tower Module.

3.12.2 Reporting

The muon optical calibration software generates a test report that summarizes compliance with CAL performance specifications. This test report will be used as a reference against which subsequent muon calibrations may be compared. In addition, off-line analysis of the calibration data generates a table of calibration constants that are used in the SAS environment.

A subset of the calibration constants and housekeeping data from the electronic calibration will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.12.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A, B, 1, 2	3	1 Scientist, 1 Engineer, 2 Technicians, 1 QE

3 – 16	2	1 Scientist, 2 Technicians, 1 QE

3.13 Mass Properties Measurement, Initial Reference

The completed CAL Tower Module will be weighed, and its physical dimensions will be measured, in accordance with LAT-PS-###. The precision of the mass measurement will be to the nearest gram. The precision of the dimensional measurements will be to the nearest 0.1 mm (TBR). The Module will be removed from its Transportation Cart as required, but for safety of the Module, the Cart will be available at all times. A Technician will confirm that the measured mass and dimensions comply with the relevant requirements. Measurements and compliance will be entered into the CAL Module Properties Database.

3.13.1 Facilities and GSE

For this measurement, the CAL Module will leave the A&T Cleanroom for the first time. Except when measurements are being made, the CAL Module will remain integrated with its Shipping Container base. The Shipping Container lid will be used to protect the Module from dirt and physical damage. The Module may be bagged and purged if ambient humidity is high.

Dimensional measurements will be made with a portable CMM. Mass measurements will be made with (TBD hardware).

3.13.2 Reporting

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.13.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	**Duration (days)**	**Personnel**
A, B	1	1 Engineer, 2 Technicians, 1 QE
1 – 16	1	1 Technician, 1 QE

3.14 EMC/EMI Testing

The first flight-model CAL – the Qualification Module (QM) – will be subjected to qualification-level electromagnetic compatibility (EMC) testing to ensure that it will neither be a source of electromagnetic interference (EMI) nor be susceptible to EMI when integrated with other components of the LAT, as specified in LAT-PS-03929. EMC/EMI testing of the remaining flight CAL Modules will be to acceptance levels. A test report will be generated for each Module.

LPT will be performed at stages within the EMC/EMI testing and at the completion of the test. An overnight muon calibration and CPT may be performed at the completion of EMC/EMI testing, at the discretion of the test director and A&T Manager.

3.14.1 Facilities and GSE

The EMC/EMI tests will be performed at NRL's EMC/EMI Test Facility.

The CAL Tower Module will be mounted in the base of its Shipping Container for transportation to the test facility, and will be hoisted to and from the EMC/EMI Test Bed (LAT-DS-03323).

The CTS system is required to operate the CAL Tower Module.

3.14.2 Reporting

A report that includes test levels, performance, and compatibility with EMC/EMI requirements will be generated. This test report shall be included in the CAL Module deliverable data package.

A subset of the test results and housekeeping data from the fucntional tests will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.14.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A	6	1 Scientist, 12Engineers, 1 Technician, EMC/EMI facility operators, 1 QE
B, 1 – 16	2	1 Engineer, EMC/EMI facility operators, 1 QE

3.15 Vibration Testing

The CAL Module will undergo vibration testing to verify its compliance with its mechanical design parameters and to demonstrate its robustness against the launch vibration environment. The vibration testing of the first flight Module – the Qualification Module (QM) – shall comprise three subsets at proto-flight levels: modal survey, sine vibration testing, and random vibration testing. Subsequent modules will undergo random vibration testing at acceptance levels. Test vibration levels and requirements are given in LAT-PS-04454.

LPT will be performed at stages within the vibration testing and at the conclusion of the test to establish that no degradation of performance has occurred. An overnight muon calibration and CPT may be performed at the completion of the vibration testing, at the discretion of the test director and A&T Manager.

3.15.1 Facilities and GSE

These vibration tests will be performed at NRL's Vibration Test Facility.

The CAL Tower Module will be mounted in the base of its Shipping Container for transportation to the test facility, and will be hoisted to and from the Vibration Test Fixture (LAT-DS-03323).

The CTS system is required to operate the CAL Tower Module.

3.15.2 Reporting

The Test Director will be responsible to generate a report that includes test levels, performance, and compatibility with vibration test requirements. This test report shall be included in the CAL Module deliverable data package.

A subset of the test results and housekeeping data from the functional tests will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.15.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A, B	4	2 Engineers, 2 Technicians, Vibe facility operators, 1 QE
1 – 16	4	1 Engineer, 2 Technicians, Vibe facility operators, 1 QE

3.16 Thermal-Vacuum Testing

The CAL Tower Module will be subjected to thermal-vacuum cycles over a wide temperature range with a CsI temperature gradient of <10C per hour, in accordance with LAT-PS-04455.

The four primary objectives of this test are:

1. To verify the performance and thermal design of the QM over the qualification temperature range of –30C to +50C.
2. To characterize the thermal balance of the QM over the qualification temperature range of –30C to +50C.

3. To verify the performance of the FM over the flight acceptance temperature range of –20C to +35C.
4. To characterize the functional performance of the QM and FM over the operating temperature range of –15C to +25C

Electrical functional testing and muon collection will occur during all tests. Tests that will occur in the thermal-vacuum environment are outlined below:

- Survival turn on sequence shall be performed once at the hot survival plateau and once at the cold survival plateau.
- Comprehansive Performance Tests (CPT) shall be conducted at each plateau of the first, fourth, and fifth test cycles.
- Limited Performance Tests (LPT) shall be conducted during thermal transitions, where system failures or intermittent problems are most likely to occur, and at each plateau of the intermediate test cycles (second and third cycles).

The broad temperature range, limited temperature derivative, required soak time, and required number of cycles dictate that duration of the complete thermal vacuum test is about two weeks (see below). Because of the long duration and expense of conducting this test, two Tower Modules will be tested together in the same thermal-vacuum chamber. Each Tower Module will be connected to its own CTS system.

Special consideration must be given to prevent hydration and/or condensation during all setup and test operations. To ensure that moisture is driven off, all thermal cycle programs shall begin with the hot cycle. To prevent moisture condensation when the program is completed, all thermal cycle programs shall end with the hot cycle. All cold cycles shall be performed in a dry environment. To prevent water condensation, a cold Module must not be exposed to ambient air.

A CPT will be performed at the completion of thermal-vacuum testing to establish no degradation of performance. An overnight MuC may be performed at the completion of the thermal-vacuum testing, at the discretion of the Test Director and A&T Manager.

3.16.1 Facilities and GSE

These thermal-vacuum cycles will be performed with NRL's Thermal-Vacuum Facility.

The CAL Tower Module will be mounted in the base of its Shipping Container for transportation to and from the Thermal-Vacuum Facility. It will be hoisted to and from the Thermal-Vacuum Test Fixture (LAT-DS-###).

The CTS system is required to operate the CAL Tower Module.

3.16.2 Reporting

The Test Director and Mechanical Systems Manager will be responsible to generate a final test report. This test report shall be included in the CAL Module deliverable data package.

Test reports of all LPT, CPT, and MuC will be archived. Trending data will be accumulated in the CAL Trending Database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.16.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A	16	1 Scientist, 2 Engineers, 2 Technicians, TV facility operators, 1 QE
B, 1 – 16	10	1 Scientist, 1 Engineer, 2 Technicians, TV facility operators, 1 QE

3.17 Comprehensive Performance Test, Pre-Ship Reference

A final Comprehensive Performance Test will be performed on the CAL Tower Module to confirm no degradation of performance during environmental testing. This test will repeat the Initial Reference Comprehensive Performance Test. Performance will be compared with that CPT to confirm no degradation.

This pre-ship reference CPT shall be the test of record to judge whether the completed CAL Tower Module complies with the relevant performance requirements.

3.17.1 Facilities and GSE

The CAL Tower Module will be mounted in the base of its Shipping Container (LAT-DS-03395).

The CTS system is required to operate the CAL Tower Module.

3.17.2 Reporting

A subset of the test results and housekeeping data from the CPT will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.17.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A, B, 1, 2	1	2 Scientist, 1 Engineer, 2 Technicians, 1 QE
3 – 16	1	1 Scientist, 1 Engineer, 1 Technician, 1 QE

3.18 Electronic Calibration, Pre-Ship Reference

The CAL Module will be calibrated following the Electronic Calibration Procedure (LAT-PS-04187). This calibration includes a charge-injection calibration of each of the 768 analog and digital electronics channels, a calibration of all 192 FLE and 192 FHE discriminators, a calibration of all 192 log-accept thresholds, and a calibration of the range-selection discriminators. Charge is injected into each analog front end at a high rate covering the full dynamic range of the electronics. Data will be logged to the CTS and analyzed with EGSE software. Raw calibration data will be archived to a long-term storage medium. Test results and performance summary will be logged to the CAL Module Properties Database.

This pre-ship reference EC shall be the test of record to judge whether the completed CAL Tower Module complies with the relevant performance requirements.

3.18.1 Facilities and GSE

The CAL Tower Module will be mounted in the base of its Shipping Container (LAT-DS-03395).

The CTS system is required to operate the CAL Tower Module.

3.18.2 Reporting

The electronic calibration software generates a test report that summarizes compliance with CAL performance specifications. This test report will be compared to the pre-thermal-vacuum and pre-vibration reports to confirm no change in instrument performance, and it will serve as a reference for the post-shipment acceptance test at SLAC. In addition, off-line analysis of the calibration data generates a table of calibration constants that are used in the SAS environment.

A subset of the calibration constants and housekeeping data from the electronic calibration will be included in the trending database.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.18.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A, B, 1, 2	1	2 Scientist, 1 Engineer, 2 Technicians, 1 QE
3 – 16	1	1 Scientist or Engineer, 1 Technician, 1 QE

3.19 Muon Calibration, Pre-Ship Reference

The pre-ship muon calibration comprises two tests: the self-triggered Muon Calibration and the externally triggered Muon Calibration (both contained in LAT-PS-04187).

The self-triggered muon calibration is identical in configuration to the initial reference, self-triggered muon calibration performed in Section 3.12. In accordance with LAT-PS-04187, muons will be accumulated for not less than 24 hours, with triggers generated internally by the CAL Module. Following the run, the data will be analyzed by EGSE software to derive scintillation light yields and light tapering response maps for the individual CDEs. The relative light yields and light-tapering functions from the muon calibration will be compared to the pre-environmental-test response to confirm no change in instrument performance.

The externally triggered muon calibration is performed with the CAL Tower Module integrated within the plastic scintillator paddles of the Plastic Muon Telescope, as given in LAT-PS-04187. Externally triggered muons will be accumulated for not less than 24 hours. Data will be analyzed by EGSE software (and optionally by off-line software) to derive a final energy calibration.

Raw calibration data will be archived to a long-term storage medium.

Following the successful conclusion of the externally triggered muon calibration, the Plastic Muon Telescope will be de-integrated from the CAL Tower Module.

This pre-ship reference MuC shall be the test of record to judge whether the completed CAL Tower Module complies with the relevant performance requirements (generally, optical performance).

3.19.1 Facilities and GSE

This calibration takes place in the A&T Cleanroom with the CAL Tower Module mounted in the Shipping Container, and data acquisition provided by the CTS EGSE. The self-triggered MuC requires no additional GSE. The externally triggered MuC requires the Muon Telescope (LAT-DS-###).

The CAL Tower Module will be mounted in the base of its Shipping Container (LAT-DS-03395). The Plastic Muon Telescope has been designed to accommodate the CAL Tower Module mounted in the Shipping Container while the test is in progress.

The CTS system is required to operate the CAL Tower Module.

3.19.2 Reporting

The Test Director will be responsible to generate a final test report. Results of the self-triggered MuC will be compared to the pre-thermal-vacuum and pre-vibration response to confirm no change in instrument performance, and they will serve as a reference for the post-shipment acceptance test at SLAC. Calibration constants derived from the externally triggered MuC will be configured for use by SAS off-line software.

Test reports will be archived. Trending data will be accumulated in the CAL Trending Database.

Raw calibration data will be archived to a long-term storage medium.

The MuC report shall be included in the CAL Module deliverable data package.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.19.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A, B, 1, 2	5	2 Scientist, 1 Engineer, 2 Technicians, 1 QE
3 – 16	5	1 Scientist, 2 Technicians, 1 QE

3.20 Mass Properties Measurement, Pre-Ship Reference

The assembled CAL Tower Module will be weighed and its physical dimensions will be measured for comparison with measurements made prior to environmental testing. The precision of the mass measurement will be to the nearest gram. The precision of the dimensional measurements will be to the nearest 0.1 mm (TBR). The Module will be removed from its Shipping Container as required, but for safety of the Module, the Container will be available at all times. The QE will confirm that the measured mass and dimensions comply with the relevant requirements.

This pre-ship reference mass properties measurement shall be the test of record to judge whether the completed CAL Module complies with the relevant dimensional and mass requirements.

3.20.1 Facilities and GSE

The CAL Tower Module will be transported in the base of its Shipping Container (LAT-DS-03395). Dimensional measurements will be made with a portable CMM. Mass measurements will be made with (TBD hardware).

3.20.2 Reporting

The measurement report shall be included in the CAL Module deliverable data package.

Operations shall be documented with approved Work Order Authorizations. Parts traceability shall be maintained within those WOAs. Signed and closed WOAs shall be referenced in the CAL Module deliverable data package.

3.20.3 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A, B	1	1 Engineer, 2 Technicians, 1 QE
1 – 16	1	2 Technicians, 1 QE

3.21 Pre-ship Review

The CAL Module and TEM are installed in the Shipping Fixture. Test Reports and associated resolution reports are assembled for presentation to the Pre-Ship Review Board. The status of all discrepancies, functional anomalies, subsystem failure-free operating hours, and out-of-tolerance levels detected during the Assembly and Test process will be presented to the Board. This review will contain all items written against the Module and the associated GSE. The disposition of all reports and actions will be referenced in, included in, or attached to a summary report, which will accompany the Module during Instrument I&T. The Module and TEM must satisfy the requirements specified in LAT-MD-01345.

3.21.1 Facilities and GSE

The CAL Tower Module will be mounted in the base of its Shipping Container (LAT-DS-03395). Reporting

The final report of the Pre-Ship Review Board shall comprise the CAL Module Acceptance Data Package.

3.21.2 Personnel

The duration and personnel required for this task are listed below for each Module.

Module	Duration (days)	Personnel
A – 16	2	Pre-Ship Review Board

3.22 Transportation to SLAC

The completed CAL Tower Modules are shipped to SLAC for integration into the LAT.

3.23 SLAC Receiving Test

The CAL Tower Modules are received at the LAT Integration site at SLAC. A CPT, ET, and MuC test suite is performed on the delivered hardware leading to a formal acceptance of the flight unit.